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Comparison of different pretreatment methods for separation hemicellulose from straw during the lignocellulosic bioethanol production

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The combustion of fossil fuels is responsible for 73% of carbon dioxide emissions into the atmosphere and consequently contributes to global warming. This fact has enormously increased the interest in the development of methods to reduce greenhouse gases. Therefore, the focus is on the production of biofuels from lignocellulosic agricultural residues. The feedstocks used for 2nd generation bioethanol production are lignocellulosic raw materials like different straw types or energy crops like miscanthus sinensis or arundo donax. Lignocellulose consists of hemicellulose (xylose and arabinose), which is bonded to cellulose (glucose) and lignin. Prior to an enzymatic hydrolysis of the polysaccharides and fermentation of the resulting sugars, the lignocelluloses must be pretreated to make the sugar polymers accessible to enzymes.

A variety of pretreatment methods are described in the literature: thermophysical, acid-based and alkaline methods.In this study, we examined and compared the most important pretreatment methods: Steam explosion versus acid and alkaline pretreatment. Specific attention was paid to the mass balance, the recovery of C 5 sugars and consumption of chemicals needed for pretreatment.

In lab scale experiments, wheat straw was either directly pretreated by steam explosion or by two different protocols. The straw was either soaked in sulfuric acid or in sodium hydroxide solution at different concentrations. For both methods, wheat straw was pretreated at 100°C for 30 minutes. Afterwards, the remaining straw was separated by vacuum filtration from the liquid fraction.The pretreated straw was neutralized, dried and enzymatically hydrolyzed. Finally, the sugar concentrations (glucose, xylose and arabinose) from filtrate and from hydrolysate were determined by HPLC.

The recovery of xylose from hemicellulose was about 50% using the sulfuric acid pretreatment and less than 2% using the sodium hydroxide pretreatment. Increasing concentrations of sulfuric acid lead to increasing conversion of hemicellulose to xylose. In contrast, increasing sodium hydroxide concentrations degrade the hemicellulose to unknown derivates. Consequently, almost no sugars from hemicellulose remain for fermentation.

The hydrolysis of sulfuric acid pretreated straw results in a maximum glucose concentration of 100 g/kg straw and a xylose concentration of nearly 30 g/kg. Sodium hydroxide pretreated and hydrolyzed straw leads to a maximum glucose concentration of 90 g/kg straw and a xylose concentration of nearly
20 g/kg.

In comparison to the two chemical pretreatment methods (sodium hydroxide and sulfuric acid pretreatment), the steam explosion pretreatment (conditions: temperature 190°C, time 20 minutes) results in a higher glucose concentration of about 190 g/kg straw and a xylose concentration of nearly 75 g/kg straw after enzymatic hydrolysis of the dried straw.

Because of the small effect the sodium hydroxide pretreatment has on xylose recovery, this method won't be used for separation and conversion of hemicellulose into xylose and arabinose. Although pretreatment with sulfuric acid achieved promising results, further research and economical considerations have to be performed.

In conclusion, the steam explosion method is still the state of the art pretreatment method for the production of lignocellulosic biofuels. Alkaline methods destroy most of the xylose part of the sugar fraction and a loss of up to 25 % of the fermentable sugars is not acceptable for a sustainable biofuel production. The acid pretreatment yields high amounts of accessible hemicellulose and cellulose, but the consumption of chemicals for acid pretreatment and neutralization has to be taken into account when considering technical implementation.